Introducing a Cogeneration System to Improve Efficiency at Ana Aslan, Romania

Project Title: Environmental Conditions Improvement by Modernization of Otopeni Thermal Plant
Leader: "Ana Aslan" National Institute of Gerontology and Geriatrics
Partners: Artemel International, Inc. – USA, ENINVEST S.A. – Romania
Location: Romania
Project Duration: February 2002 – September 2002
EcoLinks Project Investment: Total Project Investment: $ 86,700; Ecolinks grant: $ 42,670; Team Cost Share Contribution: $ 44,030

Best Practice: Transferable Solution

This EcoLinks project is a Best Practice because it successfully demonstrated a methodology for reducing greenhouse gas emissions and generating reliable and cost effective energy from a small-scale, combined heat and power (CHP) plant at a health care facility in Romania. After investigating several alternatives, a practical solution was selected that offered both economic and environmental benefits and that are appropriate under local conditions. This integrative methodology, involving a feasibility study and a good financial strategy, is transferable to other similar facilities seeking to improve energy efficiency and availability, reduce energy costs and greenhouse gas emissions, and achieve independence from the municipal utility network.

Project Summary

"Ana Aslan" National Institute of Gerontology and Geriatrics (NIGG), including the Otopeni Complex, was established in Romania in 1952. It is the first facility in the world to systematically investigate the medical, social, demographic and cultural aspects of aging and is now world renowned for its anti-aging therapies. It pioneered the isolation of an anti-aging molecule called procaine that was later used to develop Gerovital H3, an anti-aging agent.

The Otopeni Complex at NIGG consists of client treatment facilities and seventeen pavilions (approx. 20,000 square meters) that accommodate approximately 300 persons at a time. Many of the pavilions in the Complex are more than 40 years old and there is an increasing need to improve the facilities, especially the heating, wastewater treatment and waste management. Heating the Complex is costly and challenging since it involves outdated systems and is generated on the premises. Heat is supplied by a Heat Only Boiler Plant (HOB) that is designed to supply space heating and therapeutic treatment using sanitary hot water and process steam. The HOB, commissioned in 1976, covers the heat demand but given the age of the equipment, heating efficiency has dropped from an initial 92% to 73%. As a consequence, all four water boilers at the Complex operate continuously during the wintertime, at increased emissions rates and fuel cost. At present, electricity is supplied by the National Power Grid (NPG), which also incurs fairly high transmission losses and high emission levels in large, coal and oil fired power plants. In addition to heat and power generation, the biological wastewater treatment plant is in an advanced state of deterioration with minimal functioning capacity and needs to be updated.

With the support of an EcoLinks Challenge Grant, NIGG collaborated with a US partner (Artemel International, Inc.) and a Romanian partner (ENINVEST SA) to secure reliable and efficient heat and power generation at the Otopeni Complex. The technical, environmental and economic aspects of selecting and installing the most appropriate cogeneration system or, alternatively, modernizing the Heat Only Boiler Plant were investigated in order to determine the most feasible and appropriate system. The final selected alternative system consisted of a 200 kW reciprocating engine, three hot water boilers of 855 kW each and two steam boilers of 210 kW each. This solution was largely derived from calculating the future heat demand, which incorporated energy savings through building modernization and increased demand from the application of new geriatric treatments.

The main purpose of the project was to cover the Clinic's heat demand at the lowest emissions and lowest cost possible, and to ensure a consistent supply of energy. With the implementation of this system, greenhouse gas emissions and heating costs are notably reduced. CO_2 emissions are reduced by 39%; CO emissions by 33%; and NO_2 emissions by 34%. A total of $70,000 can be saved per year from reduced heating costs and by selling excess electricity to the grid. Heating costs at $ 18.3 /MWh would be 29 % less than the national heat reference sale price, and 21 % less than the Clinic's current heating costs. Apart from these savings, an important benefit arises from on – site generation, which brings higher reliability to heat and power supply.

While several financing mechanisms were considered including debt or equity financing and outright purchase, a leasing option was chosen. At a 6 % interest rate and 10-year leasing term, the lease rate is $25,716 per year. Under this financing option, the project savings practically pay for the equipment during the tenure of the lease.

Project Activities

1. Conducted an electricity and heat assessment.

The project team collected data on the current electricity and heat generation, consumption and demand, and the provision of space heating and sanitary hot water at the Otopeni Complex.

1.1 Heat demand

Total steam demand is 380 kg/h at 1.7 bar, 115^0 C, respectively in terms of heat, this represents 0.205 Gcal/h (240kW). Simultaneously, steam demand is 333 kg/h or 180 Gcal/h (210kW).

Maximum heat demand for space heating and hot water in the winter is approximately 3,100 kW/h, averaging approximately 2,000 kW/h. In the summer time, the average consumption is 350 kW/h.

1.2 Electricity demand

The installed power is 644 kW while the maximum consumption is 198 kWh. Electricity is supplied by the National Grid Company.

1.3 Heating equipment

At present, the Clinic owns a Heat Only Boiler Plant (HOB) that was commissioned in 1976 and covers the demand for heat. Given the age of the equipment, the heat efficiency dropped from an initial 92% to 73%.

The HOB consists of four Hot Water Boilers (type PaG 21) of 0.8 Gcal/h (930 kW) each, and two Steam Boilers (type PbG 21) of 0.6 Gcal/h (750 kW) each. Auxiliary equipment consists of five circulation pumps for space heating, two circulation pumps for therapeutic treatments and sanitary hot water, two feed pumps for steam boilers, three heat exchangers for hot water (5000 liters), and one tank for returned condensate (3000 liters).

The boilers are fueled by natural gas. The gas consumption was approximately 820,000 Nm^3/year in 2000, and 716,000 Nm^3/year in 2001. Unfortunately, due to high losses in the system (up to 27 %) all four water boilers need to be operate continuosly during the wintertime. The highest losses were associated with the boilers themselves.

1.4 Drinking Water Plant

Water is pumped from four wells at a rate of 11.2–13.3 m^3/hour. Daily consumption does not exceed 213 m^3.

Product(s): Comprehensive data set on the Complex's energy system and water and wastewater treatment facilities

2. Conducted an environmental assessment.

An environmental assessment of greenhouse gas emissions, wastewater and solid waste management was conducted. The annual greenhouse gas emissions (CO_2, NO_2, CO) were evaluated in accordance with the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (recommended for estimating anthropogenic emissions associated with global warming).

Based on the heat delivered annually, the following emissions were calculated for the Heat Only Boiler Plant at Otopeni: 2,560.6 tons of CO_2 per year; 6.888 tons of $NO_{2\ per}$ year; and 0.9 tons of CO per year. Solid waste amounts to two cubic meters of urban waste (e.g., PVC wastes (plates, glasses, bottles), paper waste, cotton, food waste, etc) per day and 20 kg of hospital waste (e.g., syringes, dressings, expired medicines, etc.) per day; and 220 cubic meters/day of wastewater at maximum Clinic capacity level (300 patients). Wastewater is sent to a nearby river after limited treatment in the treatment plant and after being diluted with infiltration water.

Product(s): Data on the emission levels, solid waste and waster water

3. Estimated the future demand for heat and electricity.

An analysis of the development plans of the Clinic, including the installation of new therapy equipment, was made to assess the future demand for heat and electricity. The estimate for future heat demand is 10 % lower than the current one due to the replacement of the Clinic's windows, and other building maintenance and insulation works. The demand for sanitary water is also expected to decrease by replacing the control valves with automated ones.

The annual future heat demand is estimated at 9,300 MWh/year, of which 6,000 MWh/year will go to space heating, approximately 800 MWh/year will be used for steam, and 2,500 MWh/year for health therapies and sanitary hot water.

In order to improve energy efficiency and the environmental benefits generated at the site, the analysis was extended to waste incineration and wastewater treatment as possible sources and/or consumers of electricity. The analysis indicated that the amount of solid waste and waste water generated is too small to be used as a source of energy or heat.

Product(s): Data on future heat demand

4. Developed and analyzed alternatives for improving energy efficiency and supply.

Several alternatives to generating on-site, combined heat and power (cogeneration) were considered. These technologies included: reciprocating engines, micro-turbines and fuel cells. The general benefits that these technologies share are: low emissions, cost effectiveness, cleanliness, reliability, and flexibility.

A number of top manufacturers of each technology were contacted to obtain information on system components and costs. All four options were compared based on: reliability, price, cost of operation, emissions level, and efficiency. Reciprocating engines have a major advantage in terms of both the economy of scale and the products' track record. The price is low. Spare parts and service are easily acquired. They are reliable, require little maintenance, and otherwise are suitable for the Clinic's purposes. The emissions, however, are slightly higher than those of micro-turbines or fuel cells. Micro turbines have low emissions and require very little maintenance, but do not have long-term track records and cost more than reciprocating engines. Fuel cells provide the cleanest energy source and are also efficient. They are, however, the most expensive and do not have a proven long-term track record.

Based on the local conditions and the heat and power demand, the alternatives considered were analyzed. Key parameters of the analysis included the following: capital cost, operating and maintenance cost, electrical efficiency (LHV), and heat rate. It was concluded that gas engines have the lowest acquisition cost per kWh, while fuel cells have the highest. Fuel cells, however, have the lowest operating and maintenance costs per kWh.

The emissions values of the cogeneration options were also analyzed. Sulfur dioxide emissions varied directly with the sulfur content of the fuel. In the case of natural gas, the amount is negligible. Diesel fuel and biogas, however, contain sulfur often necessitating some form of fuel cleaning. Fuel cells have the best emission characteristics, followed by micro turbines and reciprocating engines that operate on natural gas. These characteristics and the costs associated with each investigated system is presented in Table 1.

Technology	**Reciprocating Engine on Diesel**	**Reciprocating Engine on Natural Gas**	**Micro-turbine**	**Fuel Cell**
Size	30kW -6+ MW	30kW-6+MW	30-400kW	100-3000kW
Installed	600-	700	1,200-1,700	4,000-5,000
Cost ($/kW)	1,000	1,200		
Electric Efficiency (LHV)	30-43%	30-42%	14-30%	36-50%
Overall Efficiency	80 -85%	80 - 85%	80-85%	80 -85%
Total Maintenance Costs ($/kWh)	0.005-0.015	0.007-0.020	0.008-0.015	0.0019-0.0153
Emissions	NO_x: 9	NO_x: 0.7-13	NO_x: 9-50ppm	NO_x: <0.02
(gm/bhp-hr unless otherwise noted)	CO: 0.3-0.7	CO: 1-2	CO: 9-50ppm	CO: <0.01

Table 1. Costs of Each Cogeneration System

A number of top manufacturers of each technology were contacted to obtain information on system components and costs as follows:
1) For Reciprocating Engine Manufacturers the following manufacturers were considered: Caterpillar, Cummins, Kohler and Waukesha Engine.
2) For Micro turbine Manufacturers: ALM Turbine, Capstone Turbine Corporation, Elliott Energy Systems, Ingersoll Rand Energy.
3) For Fuel Cell Manufacturers: Siemens Westinghouse and United Technologies.
4) For Packaged (Compact) Systems Suppliers: Genergy Power Solutions and Tecogen.

Product(s): 1) Alternatives for on-site cogeneration energy systems including an assessment of the technical feasibility of incorporating a wastewater treatment plant and a waste incinerator in the energy scheme 2) List of manufacturers of cogeneration technologies

5. Selected best energy system option.

In order to assure that the heating system would run at maximum efficiency while meeting seasonal heating demands, the appropriate cogeneration module was selected. For comparative purposes and to test the benefits of the cogeneration, a solution featuring only the modernization of the existing Heat Only Boiler plant was also considered.
The difference in overall efficiency among alternative cogeneration systems is negligible. The analysis made by the project team indicated that the most economically and technically feasible solution for Otopeni Clinic is to replace the existing Heat Only Boiler plant with reciprocating engines.
The cogeneration module would be responsible for supplying the Clinic with treatment and sanitary hot water under Option I, and treatment and sanitary hot water and steam demand under Option II. Three possible options for equipment configuration were analyzed as follows:

Option I
The existing Heat Only Boiler plant is replaced by a Combined Heat and Power (CHP) plant that includes: 1) One cogeneration module, consisting of one reciprocating engine (200 kWh installed electricity capacity) and one heat recovery boiler (312 kW installed heat capacity) to produce electricity and heat to meet the average heat demand for hot water; 2) One steam boiler of 210 kW to meet heat demand for process steam; and 3) Three hot water boilers of 855 kW to produce hot water for space heating during the winter.

Option II
The existing Heat Only Boiler Plant is replaced by a Combined Heat and Power (CHP) plant system that includes: 1) One cogeneration module consisting of one reciprocating engine of 400 kW installed power; one heat recovery boiler of 312 kW installed hot water; one steam boiler of 210 kW; and one hot water boiler of 855 kW with the boiler generating space heating during the winter.
The cogeneration module would produce electricity and heat to meet the average heat demand for sanitary hot water and processing steam.

Option III

The existing Heat Only Boiler plant is replaced with a new one including: four hot water boilers of 855 kW to meet space heating demands; and two steam boilers of 525 kW to meet the heat demand for domestic warm water and to process steam.

A comparison of costs by each co – generation system was conducted.

Product(s): 1) Data on technical and environmental performance and costs associated with three cogeneration options

6. Conducted an environmental assessment of each option.

An assessment of the emission savings under the different options was made and is presented in Table 2.

Emissions and Savings: Current Situation and Options I, II, III	CO2 (tons/yr)	Savings (%)	CO (tons/yr)	Savings (%)	NO2 (tons/yr)	Savings (%)
Emissions under current situation	3941	N/A	1.3	N/A	9.77	N/A
Options I and II	2408	39	0.86	33	6.47	34
Option III	3426	13	1,12	14	7.55	23

Table 2. Emission Savings for Each Option

7. Estimated Implementation Costs of Modernizing HOB Plant

The project team conducted a financial analysis (Net Present Value, Internal Rate of Return, and Discount Rate) of the modernization of the HOB plant and the Wastewater Treatment Plant. The possibilities considered for the HOB plant operations were:

1) Replace the existing HOB with a small cogeneration system with a reciprocating engine (200 kW), three hot water boilers (855 kW), and a steam boiler (210 kW);
2) Replace the existing HOB with a larger cogeneration system with a reciprocating engine (400 kW) and three hot water boilers (855 kW); and
3) Modernize the existing HOB by replacing the existing hot water boilers (855 kW) and the steam boilers (524 kW) with more efficient ones.

An analysis of financial indicators and cash flow was performed for each option based on the same gas and electricity rates. In the case of Options I and II (with cogeneration modules), the Complex electricity demand of 1,032 MWh/year is supplied by the cogeneration system and the excess of 550 MWh/year is sold to the grid.

A summary of the financial indicators is presented in Table 3.

Specification	Unit	Option I	Option II	Option III
Net Present Value	US$	131,000	244,000	300
Internal Rate of Return	%	15	18.5	12
Discount rate	%	12	12	12

Table 3. Summary of Financial Indicators

Proposed improvements regarding the Wastewater Treatment Plant included:

1) Upgrading the existing facility for $28,000; or
2) Replacing it with a new and modern treatment plant for $ 97,000.

The team recommended replacing the existing HOB with a small cogeneration system with a reciprocating engine (200 kW), three hot water boilers (855 kW), and a steam boiler (210 KW); and upgrading the existing Waste Water Treatment Plant. The choice of the smaller cogeneration module is justified by the smaller investment costs but also by financial prudence regarding selling and collecting payments for large amounts of electricity from external clients.

Product(s): 1) Cash flow analysis for two cogeneration systems and one Heat Only Boiler plant 2) Solution recommendations

8. Reviewed financing options.

Several financing mechanisms were reviewed including debt financing with commercial banks, multilateral development banks, and export credit agencies; equity financing; self-financing; and operational or capital leasing. Given the size of the investment and the legal status of the facility, debt or equity financing was not considered an attractive option.

The team recommended leasing as the preferred financing solution. A detailed analysis was made for operational leasing under the following terms: discount rate: 12 %; lease period: 10 years; interest rate: 6%; no advance payment, no residual value; and electricity sale tariff: $39/kWh. The costs of installation and commissioning would be covered by the project sponsor in the first year. A leasing rate of $2,600/month was considered feasible for the Complex.

Arrangements were also made for the Leader to become a licensed power supplier with the National Energy Regulatory Authority.
Product(s): 1) Investments financing options and recommendation 2) Documentation for independent power production license

9. Conducted a seminar on the Project.

A seminar was conducted on the Otopeni Clinic to present the Project findings to the Ministry of Environmental Protection and the Ministry of Health, Regional Heath Care Institutions, and representatives from hospitals and other treatment facilities.

Product(s): 1) Presentation 2) Hand out materials

Project Benefits

There are several benefits generated by this project. They include capacity building, through very good teamwork and dissemination of results in the health care sector, and notable economic and environmental benefits including cost savings and reductions in greenhouse gas emissions from improving energy efficiency.

Capacity Building Benefits

Through the transfer of know-how from the US partner (Artemel International, Inc) and the Romanian partner (ENINVEST SA) to NIGG, the Otopeni Clinic Complex learned how to evaluate and improve its economic and environmental performance. A methodology was presented that systematically evaluated various technological options. A detailed environmental and economic analyses of each options was performed in order to select the most suitable one for the Clinic.

This process involved solid, on-the-job training for the Clinic investment and maintenance staff. With this training, the staff at the Ana Aslan Clinic initiated the process to become an independent power producer.

The Project activities and results were shared in a Project Seminar involving representatives of other health care organizations and facilities. As a result, similar projects are now being considered in other parts of Romania.

Environmental Benefits

The environmental benefits associated with the replacement of the existing Heat Only Boiler Plant (overall efficiency: 72.5 %) with a modern, combined heat and power unit (overall efficiency: 80 – 90 %) are numerous. The total CO_2 emissions are expected to decrease by 39 % (1532 t/yr.), the CO emissions by 33 % (430 kg/yr.) and the NO_2 emissions by 34 % (3300 kg /yr.). Additionally, power transportation losses through the networks are practically reduced to zero with on-site generation. A cogeneration system consumes approximately 35 % less fuel than a classic fossil fuel power plant. This means a similar reduction in greenhouse gas emissions.

Economic Benefits

This project not only provides environmental benefits but also generates economic benefits. Under the recommended option, the project generates a Net Present Value of approximately $131,000 and has an Internal Rate of Return of 15%. The heat unit cost is $18.3/MWh (21 % lower than the actual cost and 29 % lower than the natural reference heat tariff). Natural gas consumption is reduced by 33 %, representing around $70,000 /year, including the economy in fuel consumption in order to produce the amount of electricity that was bought from the NPG before project implementation.

Lessons Learned

The following lessons were learned during this project:

- Good cooperation and sustained communication between the three project partners is essential for the success of the project.
- Previous work experience and collaboration between partners facilitates the project's development.
- Procurement of equipment for state owned entities could be very burdensome and lengthy. This challenge, however, can be overcome by starting the procurement process as early as possible.

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